Linking stream fish assemblages to hydrologic alteration along a gradient of urbanization





Allison H. Roy*, Mary C. Freeman, Byron J. Freeman
Seth J. Wenger, William E. Ensign, & Judith L. Meyer

University of Georgia
Kennesaw State University

*Currently ORISE fellow with the U.S. EPA, Cincinnati, Ohio

This research was funded by the University of Georgia Research Foundation and a U. S. Fish & Wildlife Service Habitat Conservation Planning Grant.

Hydrologic Alteration via Urbanization

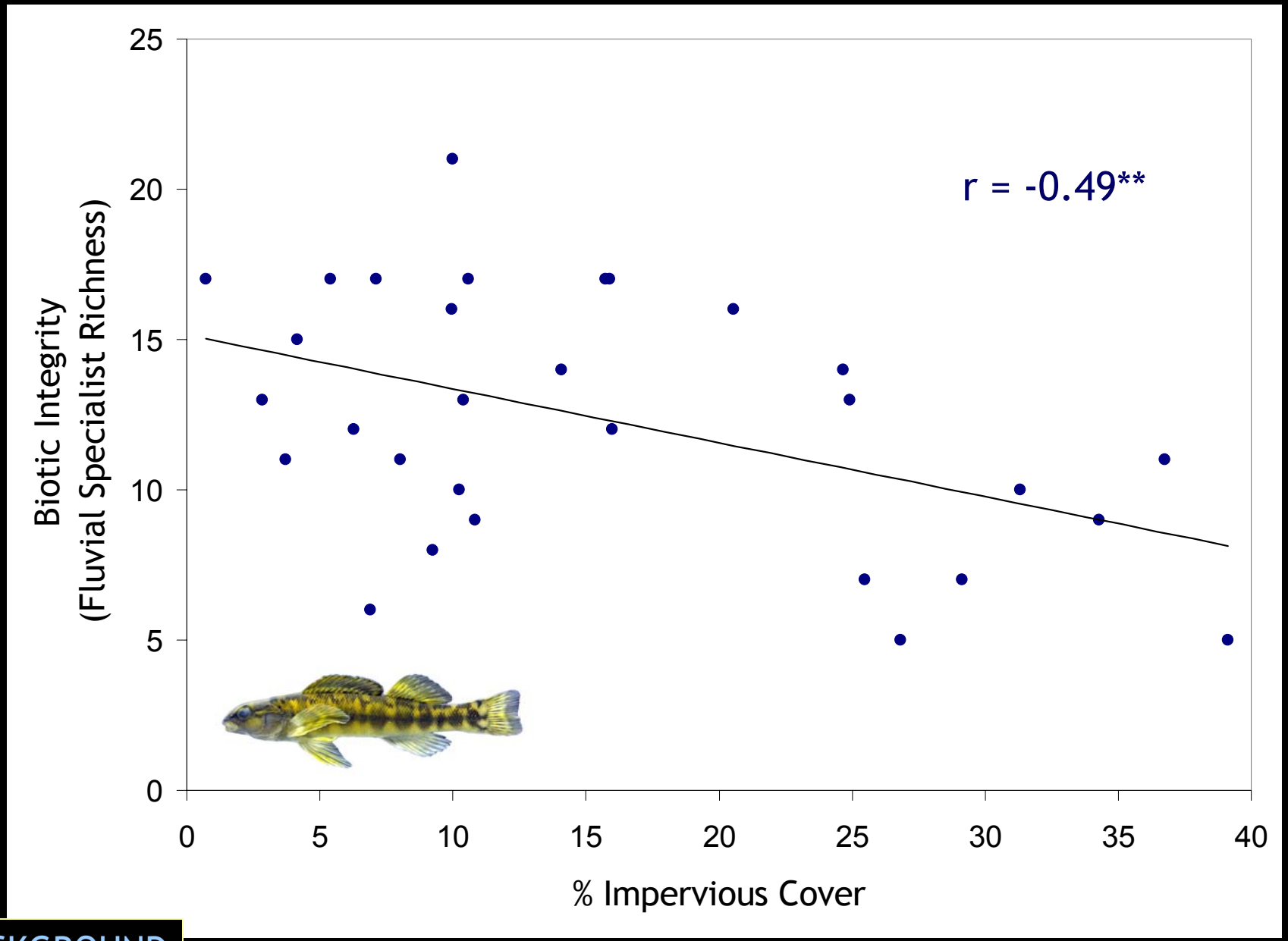
Deforestation
Impervious surfaces
Soil compaction

RUNOFF

<u>IN-STREAM EFFECTS</u>:
flashy flows
bed scour
bank erosion

BACKGROUND

Evidence of Reduced Biotic Integrity with Urbanization



BACKGROUND

Objective

To determine extent to which hydrologic alteration accounts for the negative relationship between impervious cover and stream fish assemblages.

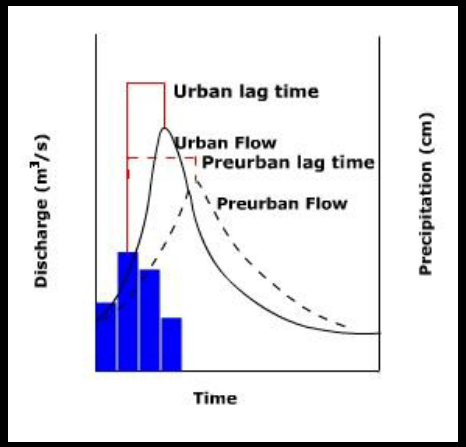
Additional Questions:

1) What aspects of hydrology are most important for fishes?
2) What characteristics of fish assemblages are most sensitive?

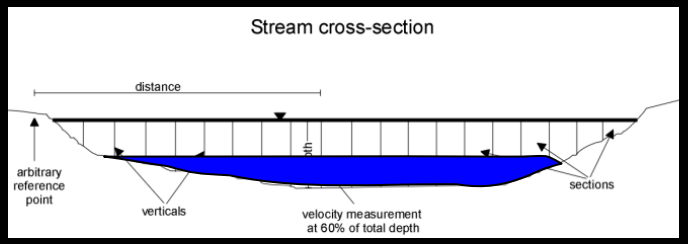
BACKGROUND

Possible Mechanisms of Hydrologic Impact on Fish Assemblages

Increased "Flashy" Flows



Reduced Baseflows



Altered Hydrology

Increased Stormflows

Reduced Baseflows

Reduced Habitat Quality (% fines)

Increased Channel Incision (riffle freq.)

Reduced Water Quality

Physical Washout

Reduced Habitat Availability

Increased Temper-ature

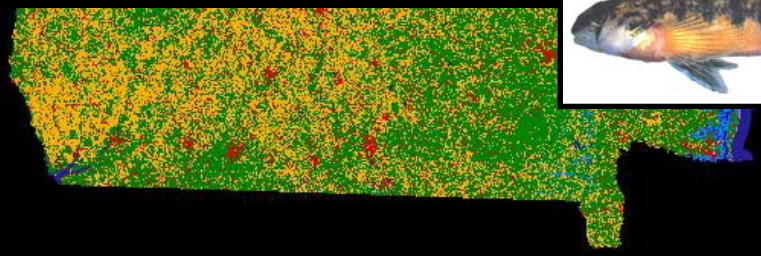
Fish Assemblage Integrity

BACKGROUND

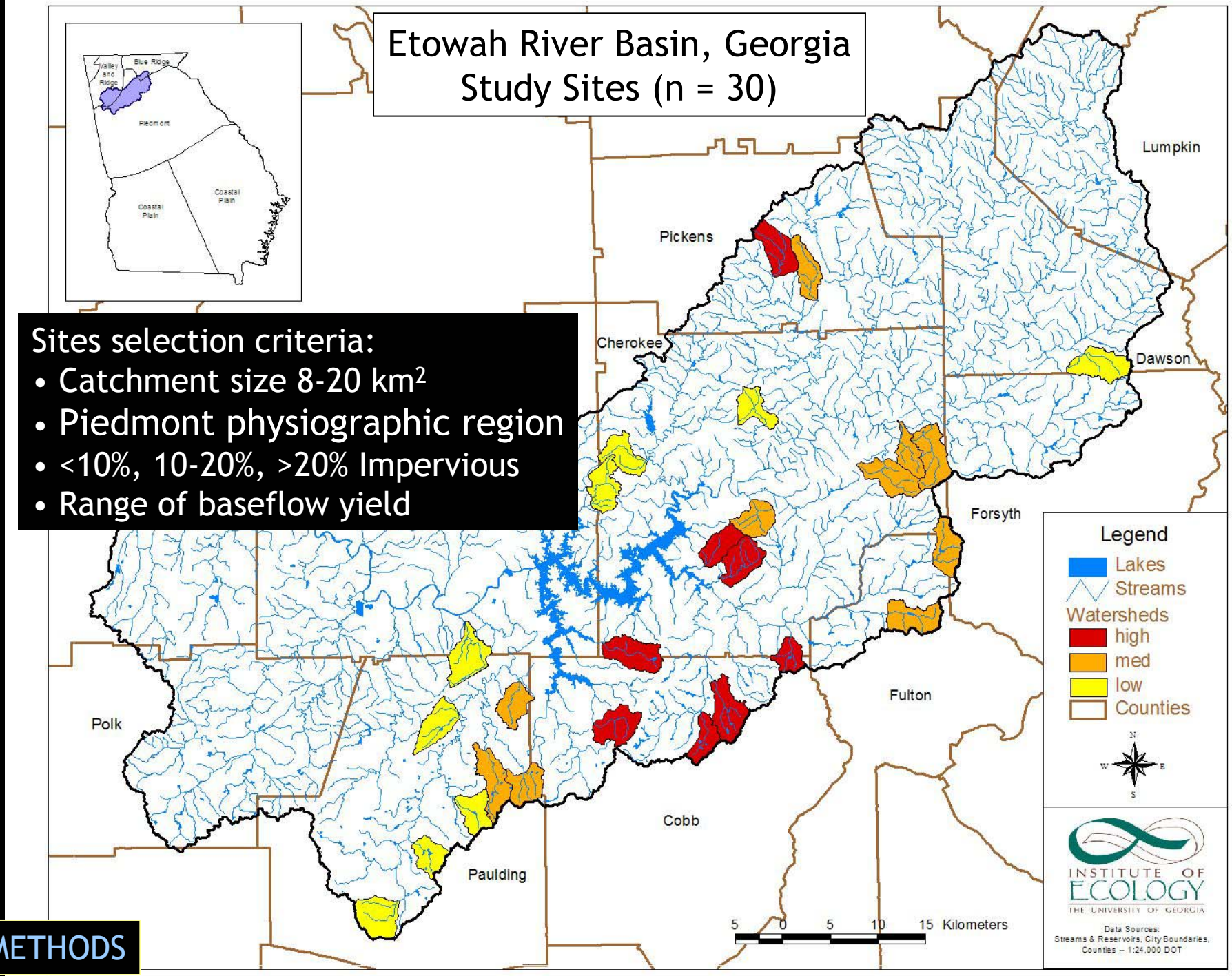
Etowah River Basin
Georgia

A hotspot of stream fish diversity and endemism:

- ~76 extant fish species, 4 locally endemic fish species
- ~51 extirpated mussel species
- 3 federally listed & 7 imperiled fishes



BACKGROUND


Etowah River Basin, Georgia
Study Sites (n = 30)
Valley and Ridge
Blue Ridge
Piedmont
Coastal Plain
Coastal Plain
Sites selection criteria:
• Catchment size 8-20 km2
• Piedmont physiographic region
• <10%, 10-20%, >20% Impervious
• Range of baseflow yield
Lumpkin
Pickens
Cherokee
Dawson
Forsyth
Fulton
Polk
Cobb
Paulding
Legend
Lakes
Streams
Watersheds
high
med
low
Counties
N
W
E
S
5 0 5 10 15 Kilometers
INSTITUTE OF ECOLOGY
THE UNIVERSITY OF GEORGIA
Data Sources:
Streams & Reservoirs, City Boundaries, Counties -- 1:24,000 DOT
METHODS

AquaRods
(water depth loggers)

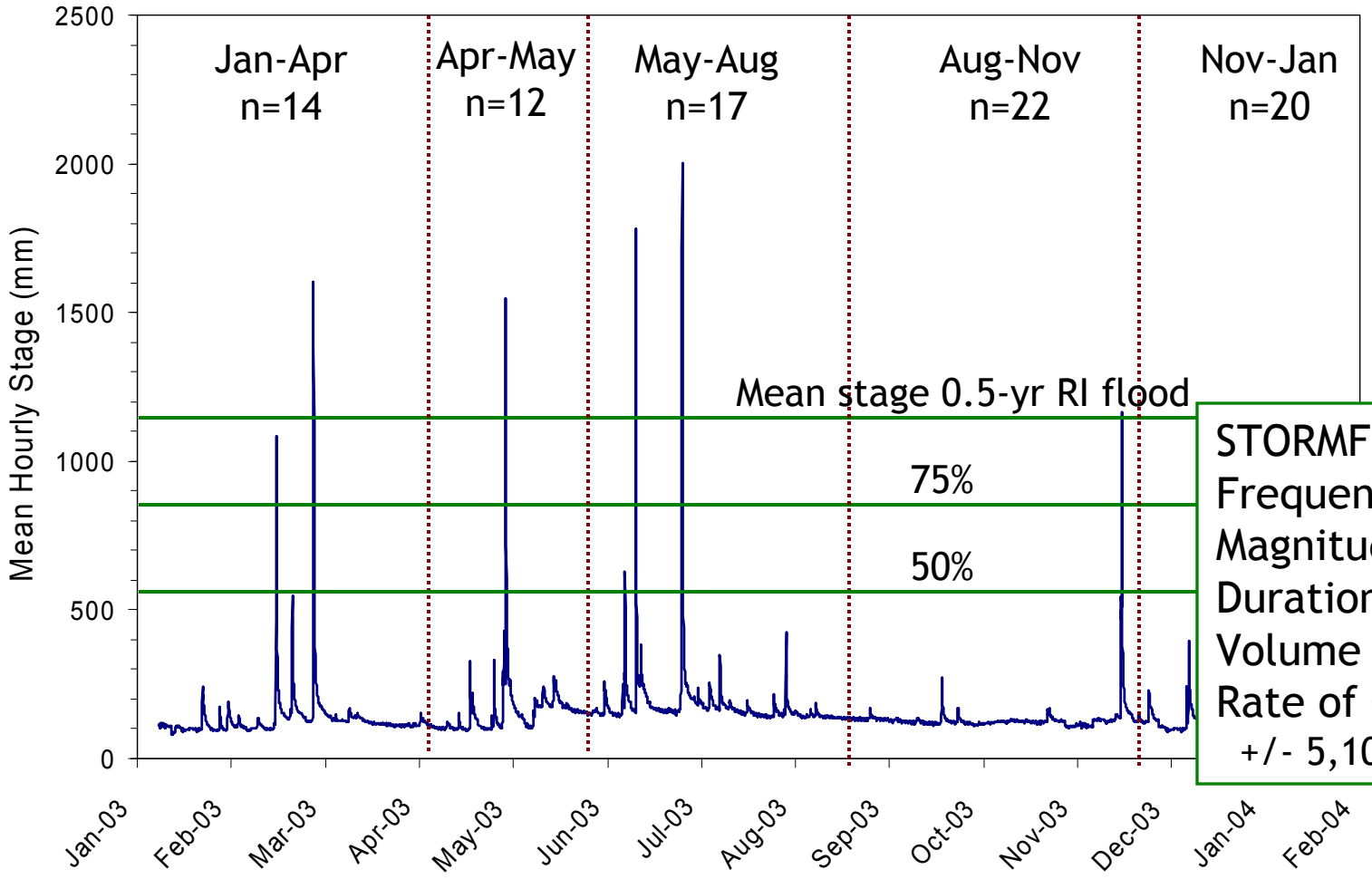
Datalogger programmed to record water level hourly & with change in water level

Sensor uses capacitance (difference in electric properties of air & water) to measure stage

METHODS

Hydrologic Alteration Variables

BASEFLOW
Magnitude min daily stage & min 7-day stage
Magnitude & Duration <25,10,5%ile



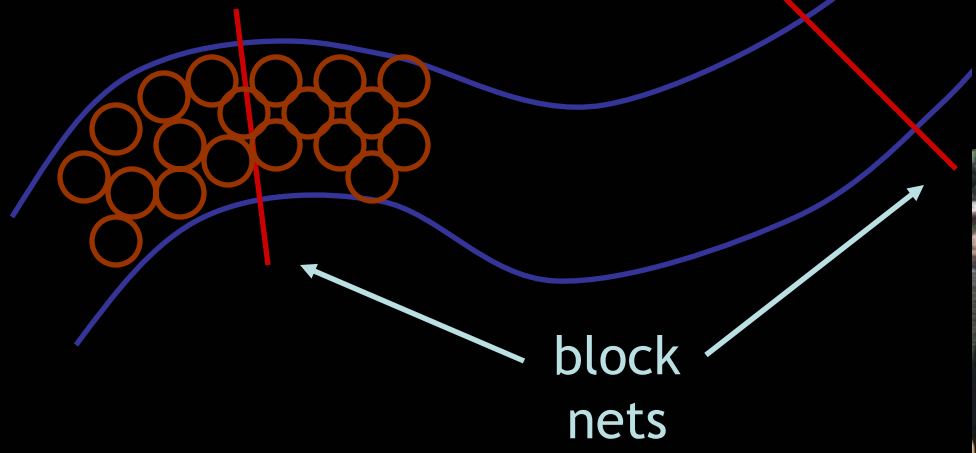
STORMFLOW
Frequency
Magnitude
Duration
Volume
} >50%,75%, & 100% 0.5-yr RI flood
Rate of Change
+/- 5,10,20 cm

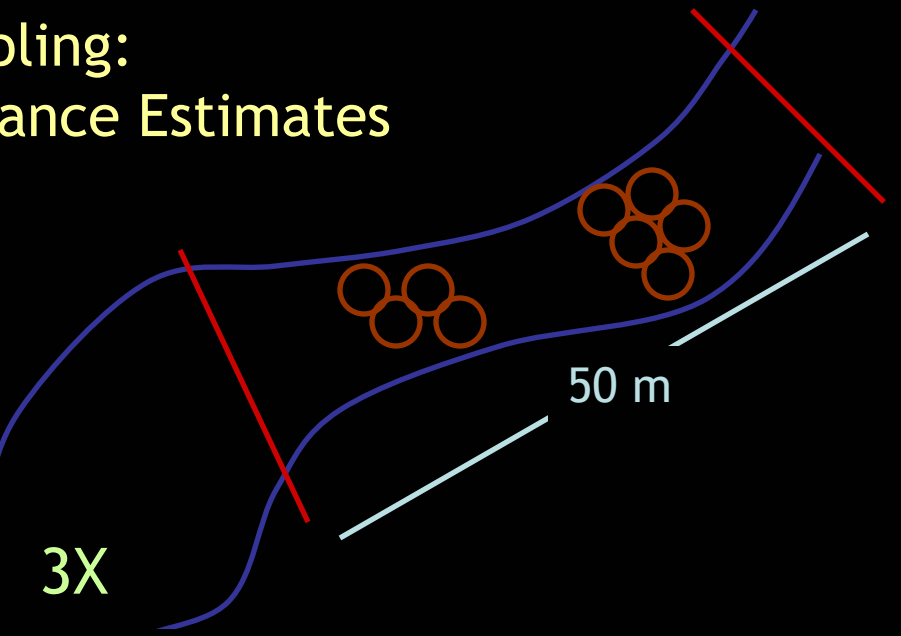
METHODS

Fish Sampling:
Richness & Abundance Estimates

1) Three 50 m reaches sampled
   → calculate species detectibility
   → estimate RICHNESS

2) One 50 m reach sampled 3X
   → calculate capture efficiencies
   → estimate ABUNDANCES

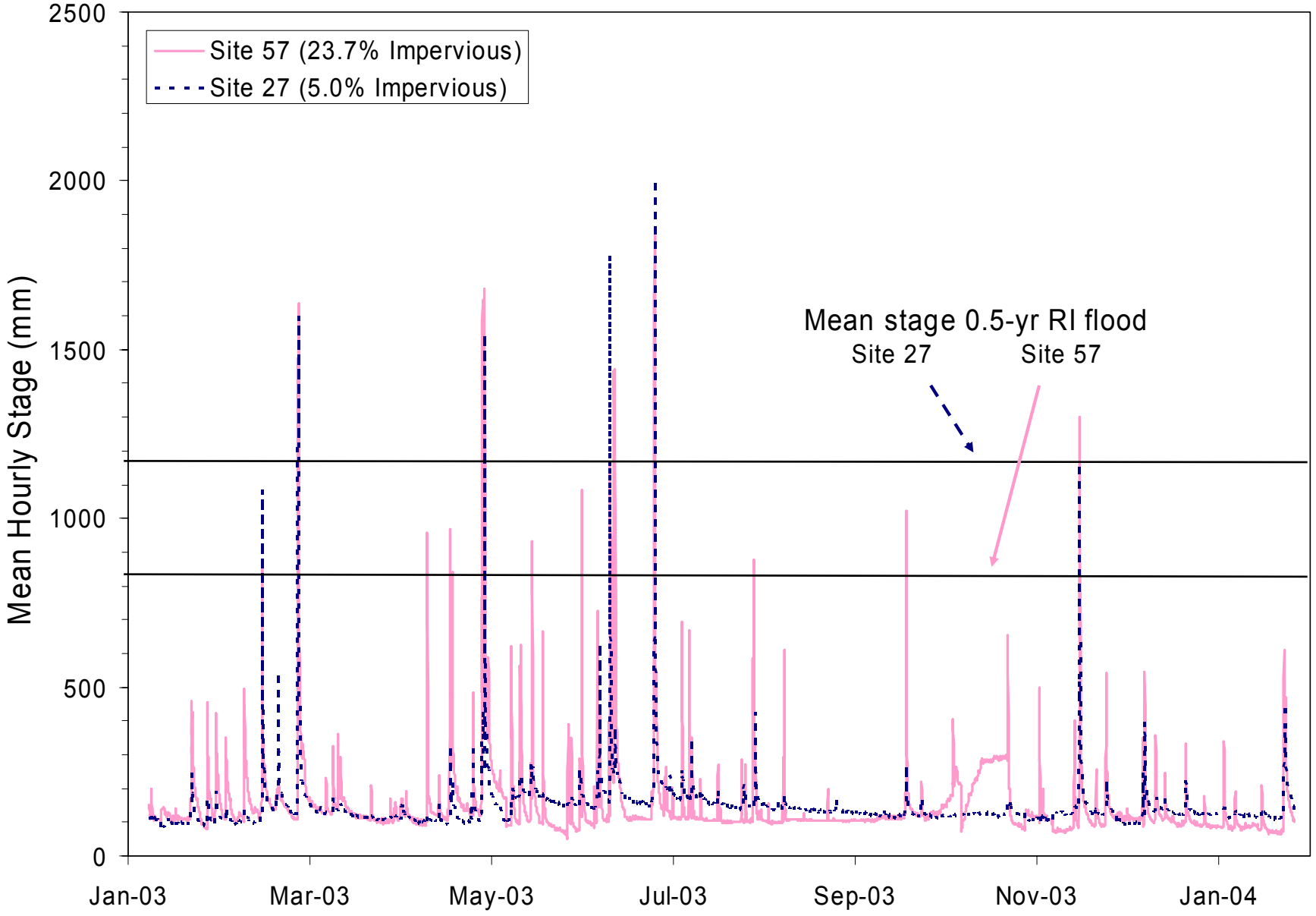




Fish Assemblage Measures:
- fluviual specialists vs lentic tolerants
- sensitive species
- endemics vs cosmopolitans

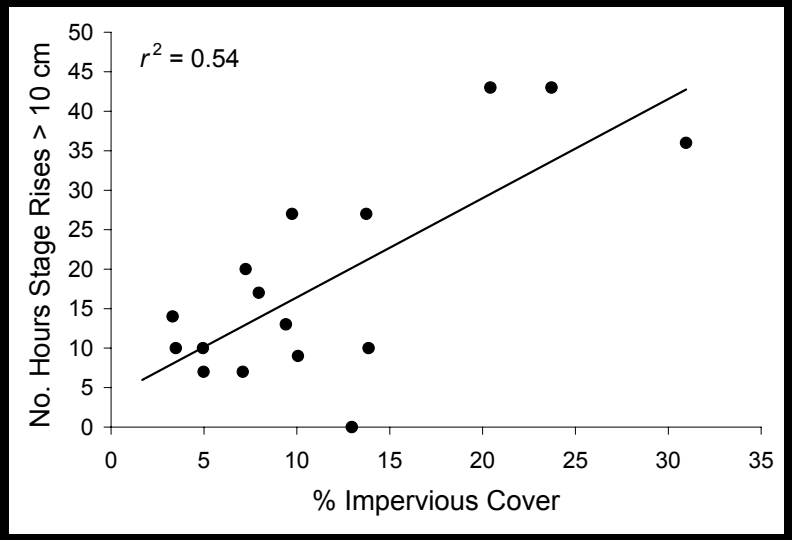
METHODS

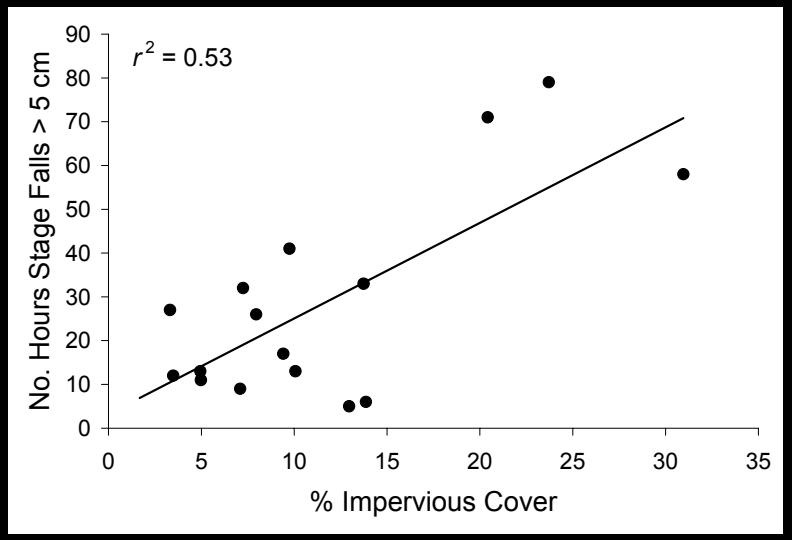
Impervious Surface Cover Affects Stream Hydrology (n=16 sites)

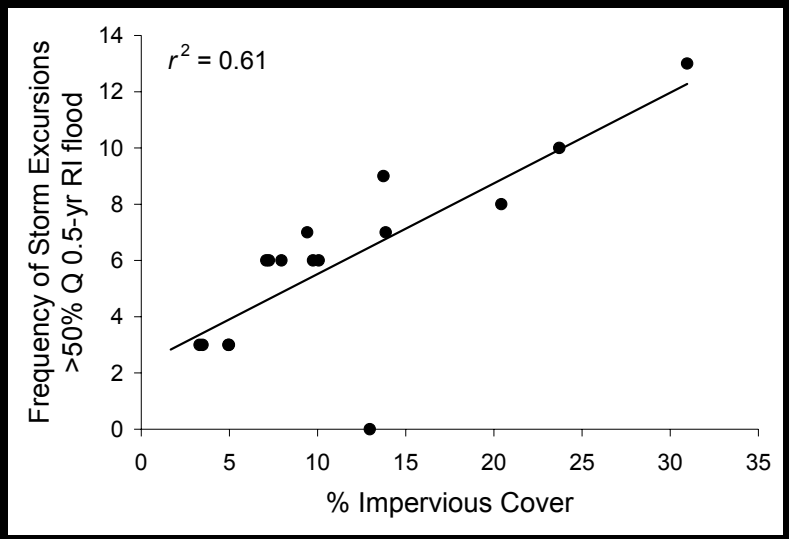


RESULTS

Increased Frequency of Large Storms & Storm Flashiness with Increased % Impervious Cover in Subcatchment (May-Aug.)

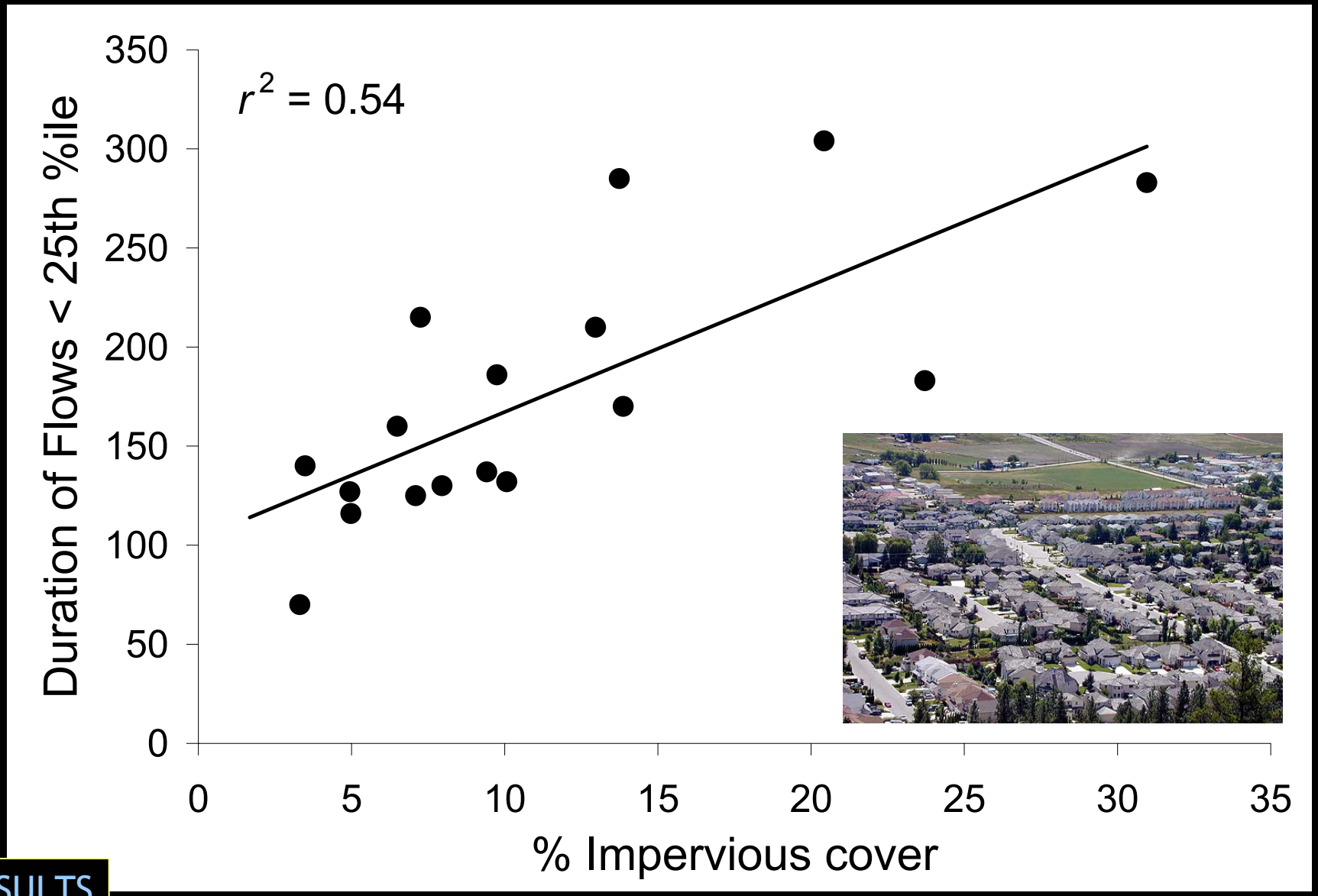






RESULTS

Increased Duration of Low Flows with Increased % Impervious Cover in Subcatchment (Aug.-Nov.)



RESULTS

Principal Components Analysis of Hydrologic Variables

Summer (15 May-7 Aug.)	Correlation with % Impervious	% Variance Explaianed	Variable Loadings
Baseflow (86.9%)			
PCA 1	0.04	53.4	Magnitude
PCA 2	-0.02	22.3	Duration
PCA 3	0.44	11.2	Duration
Stormflow (92.3%)			
PCA 1	0.64	47.3	
PCA 2	-0.52	21.7	
PCA 3	-0.41	14.6	
PCA 4	0.00	9.0	
Autumn (15 Aug.-4 Nov.)			
Baseflow (89.2%)			
PCA 1	-0.08	75.6	Magnitude
PCA 2	0.70	13.6	Duration
Stormflow (85.4%)			
PCA 1	0.70	64.0	All
PCA 2	-0.22	14.1	Mix
PCA 3	0.31	7.3	Mix

Used PCAs and % fines in riffles to predict fish assemblages with multiple linear regression analysis

RESULTS

Tolerants & Cosmopolitans Related to Altered Stormflows & Baseflows

Results of Multiple Linear Regression Analyses

LENTIC TOLERANTS

- More species with more prolonged autumn low flow durations (r^2= 0.67)

- Higher abundances with
  a) reduced summer storm magnitude (partial r^2= 0.43)
  b) reduced autumn low flow magnitude (partial r^2=0.24)

lentic tolerant & cosmopolitan

COSMOPOLITANS

- More species with
  a) more prolonged autumn low flow durations (partial r^2=0.38)
  b) increased summer stormflow volume/duration (partial r^2=0.19)

- Higher abundances with more prolonged summer low flow durations (r^2=0.35)

RESULTS

Endemics & Sensitives Related to Stormflow & Sediment Alteration
Results of Multiple Linear Regression Analyses

ENDEMIC SPECIES

- More species with reduced summer stormflow alteration (r^2=0.31)

SENSITIVE SPECIES

- More species with
  - a) reduced summer stormflow alteration (partial r^2=0.39)
  - b) lower % fine sediment (partial r^2=0.18)
  - c) reduced summer stormflow volume/duration (partial r^2=0.14)

- Higher abundances with
  - a) lower % fine sediment (partial r^2=0.46)
  - b) reduced autumn stormflow alteration (partial r^2=0.25)
  - c) reduced autumn stormflow magnitude, volume, & duration (partial r^2=0.12)


endemic & sensitive

RESULTS

Altered Hydrology

Increased Stormflows

Reduced Baseflows

Weak Relations
(Adj. R^2=0.22 to 0.67)

Fish Assemblage Integrity

→ increased % impervious cover resulted in altered stormflows & autumn baseflows

→ increased stormflows (and % fine sediment) predicted sensitive species

& reduced baseflows predicted lentic tolerants and cosmopolitans

CONCLUSIONS

Despite potential complexity, still see relations between hydrologic alteration & fishes

Altered Hydrology

Increased Stormflows

Reduced Baseflows

impoundments
nutrient loading
sediment loading
contaminant loading
habitat fragmentation
riparian deforestation

Slope (-)

(+,-)

(+)

(+)

(+)

(+)

(+)

(-)

Reduced Habitat Quality (% fines)

Increased Channel Incision (riffle freq.)

Reduced Water Quality

Physical Washout

Reduced Habitat Availability

Increased Temper-ature

(-)

(-)

(-)

(+,-)

(-)

(-)

Fish Assemblage Integrity

CONCLUSIONS

Hydrologic Alteration Predicts Fish Assemblages In Small, Urbanizing Streams





22-67% variation explained by hydrologic variables
(2-36% higher than relationship with impervious)

1) What aspects of hydrology are most important for fishes?

→ multiple aspects of stormflow alteration
→ unclear importance of baseflows

2) What characteristics of fish assemblages are most sensitive?

→ groups of species can respond differently
→ species traits (e.g., specialists/generalist) important

CONCLUSIONS

Implications for Stream Fish Protection

Requires holistic approach to watershed management

1) Reducing frequency, magnitude, volume, and duration of peak flows and flow "flashiness"

2) Maintaining adequate low flows in streams throughout the year

3) Reducing fine and unstable bed sediments

4) Minimizing impervious cover and maintaining forest cover in catchment and riparian areas

CONCLUSIONS

Management Questions & Decisions

1) Is source infiltration of stormwater a cost-effective strategy?
   (Or are centralized stormwater management options better?)

2) How much infiltration is necessary?
   (100% infiltration of a 2-yr storm event?)

3) Are fishes a good surrogate for stream ecosystem impairment?
   (Or are invertebrates more appropriate?)

TOOLBOX:
- adaptive management
- adaptive experimentation
- decision support modeling

CONCLUSIONS